

The Relation of Mechanical Properties of Wood and Nosebar Pressure in the Production of Veneer^{1,2}

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Observations of checking frequency, depth of check penetration, veneer thickness, and surface quality were made at 20 machining conditions. An inverse relationship between depth of check and frequency of checking was established. The effect of cutting temperature was demonstrated, and strength in compression perpendicular to the grain, tension perpendicular to the grain, and rolling shear was determined at 4 temperatures. The mechanics of veneer formation is discussed with respect to the 2 basic veneer types observed.

WOOD VENEERS REPRESENT, in our present-day economy, a product of countless commercial and industrial applications. Furniture, plywood, molded veneer products, boxes and crates are, to mention but a few, well-established uses of veneer.

Although veneer is a common and accepted wood product, little basic research has been directed toward an understanding of the veneer-cutting process. Information accumulated in the past, although of recognized value, has largely been obtained from experience. Lathe checks, surface irregularities, thickness limitations, and varied production techniques are present obstacles to continued industrial progress.

It follows that basic research in the field of veneer-cutting is needed. It is obvious, however, that a comprehensive study of the many aspects of veneer-cutting would be of a magnitude beyond the scope of an individual research effort. The work described herein, therefore, endeavors to establish what takes place when wood is cut into veneer, and pursues the relationships of mechanical properties of wood and nosebar pressure. The study is directed primarily to a consideration of the rotary-cutting process.

Review of the Literature

Although numerous publications may be found in veneer-cutting literature pertaining to production methods and techniques, only limited material concerning the fundamental aspects of veneer formation has been published.

¹ Second-place winner in the 1957 Wood Award competition.

² A condensation of a thesis submitted for the degree of Master of Wood Technology at the University of Michigan.

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Rotary veneer-cutting studies by Fleischer (1)³ have revealed that an optimum knife angle exists for a given species and thickness to produce veneer with a smooth, uniform surface. Further, Fleischer has shown that, in general, the cutting angle should increase as the thickness of the veneer cut decreases, and that a reduction in the horizontal nosebar opening will result in veneer that contains fewer lathe checks per inch.

Kivimaa (2), by use of a tensile test to determine veneer quality, has demonstrated that an optimum nosebar opening exists for a given species.

In work concerning veneer smoothness, Lutz (3) has shown that smoothness of knife-cut veneer is affected by the orientation of wood fibers, the annual rings, and the wood rays with respect to the plane of the cut.

Behavior of individual wood cells during slicing has been investigated in Canada (4). Wood cells were observed to be compressed by the nosebar and knife edge and by the resistance caused by friction against the nosebar face and the knife back. In addition, important tension stresses were observed acting in front of the knife edge in an approximately radial direction.

The investigations summarized above provide plausible foundation to assume that mechanical properties of wood are an important factor in the veneer-cutting process.

Nomenclature

Considerable confusion exists in the veneer industry as to the application of various descriptive terms used in the veneer-cutting process. Because of the common use of several manufacturing methods and the ambiguities of tool

³ Numbers in parentheses refer to Literature Cited at the end of this paper.

geometry, a description of cutting nomenclature is a necessary antecedent to further discussion.

The terminology adopted for use in this study is defined below, with geometrical relationships shown in Fig. 1.

- Line AB—A line perpendicular to a line tangent to the work and passing through the cutting edge of the knife.
- C—Cutting angle, the angle between the face of the knife and line AB.
- D—Sharpness angle of the knife.
- E—Clearance angle, the angle between the back of the knife and line AB.
- F—Vertical nosebar opening, the vertical distance between the maximum point on the nosebar and a plane described by the cutting edge of the knife.
- G—Nosebar bevel, the angle between the nosebar and the horizontal.
- H—Horizontal nosebar opening, the horizontal distance between the nosebar and Line AB.

Cutting velocity—The velocity of the work piece relative to the knife and nosebar.

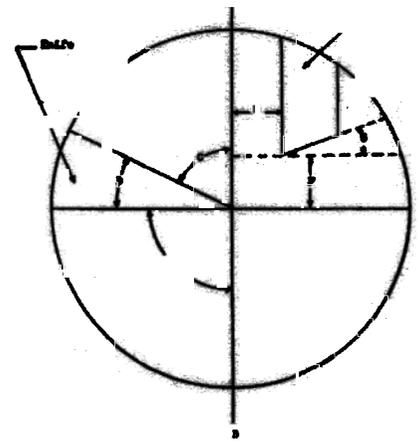


Fig. 1.—Geometrical relationships in orthogonal cutting of veneer.

Purpose and Approach

The purpose of this study was to indicate how mechanical properties of wood and nosebar openings affect the quality of wood veneer.

Exploratory cutting investigations suggested several general areas of research. Both horizontal and vertical nosebar openings, as well as cutting angle, were observed to effect veneer quality. Further, it was indicated that higher cutting velocities may materially increase checking.

While it is recognized that all the above factors influence the veneering process, it was necessary that a limitation of scope be imposed to consider only those variables within the magnitude of an individual study.

The vertical opening was determined to be the more critical nosebar adjustment, and was selected as a variable while horizontal nosebar opening was held constant. In addition, it was felt that more informative data would be obtained if cutting velocity and cutting angle closely approximated current practice.

Further, it was recognized that the use of production-size equipment presented serious limitations in both experimental design and control of cutting variables. A method was needed to produce veneer on a small, experimental scale with precise control of cutting conditions. Orthogonal cutting perpendicular to the grain, as suggested in the wood-machining literature by Franz (5), presented a favorable solution to the problem.

In orthogonal cutting of veneer, the knife edge and nosebar are perpendicular to the direction of relative motion of the cutting fixture and work piece. This generates a plane surface parallel to the original work surface. If a small segment of the outer periphery of a large veneer bolt is considered to approach a straight line, small veneer strips produced experimentally by orthogonal cutting may be considered analogous to veneer produced by the rotary-cutting process.

During the cutting of veneer, preliminary observations indicated that, among other stresses, the knife may induce stresses in the wood in tension perpendicular to the grain, compression perpendicular to the grain, and rolling shear. Concurrently, the nosebar may produce stress in compression perpendicular to the grain and rolling shear. It follows that the strength of a given species in these properties is an important consideration in analyzing the cutting characteristics of the wood.

Most strength properties of wood decrease as temperature increases. The degree of strength change has been

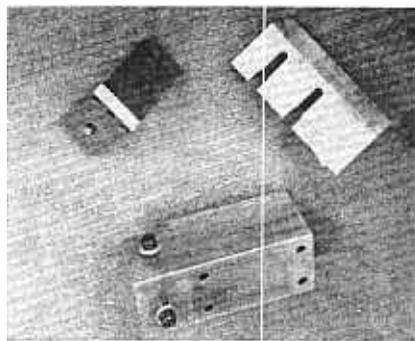


Fig. 2.—Disassembled orthogonal veneer-cutting fixture, showing knife, nosebar, and mounting.

demonstrated to bear a linear relationship to specific gravity and moisture content. Sulzberger (6) has shown that, for a number of species tested at 15 per cent moisture content, maximum crushing strength, modulus of rupture, and modulus of elasticity decrease from about 2.5 to 5.0 per cent for each 10° F. temperature change. Greenhill's (7) studies of the relation of temperature and moisture content on wood properties reveal that, at 180° F., the tensile strength and modulus of elasticity perpendicular to the grain are reduced $\frac{1}{3}$ to $\frac{1}{2}$ of their value at room temperature.

Therefore, by altering the temperature of several woods while cutting at various vertical nosebar openings, it was possible to study how veneer quality was affected by the relationships of wood mechanical properties and nosebar pressure.

Experimental Procedure

Design of the Experiment: A total of 20 cutting conditions with three replications were used to study the interaction of mechanical properties and nosebar pressure. The following experimental design was adopted:

- 1 Species—Yellow birch (*Betula lutea* Michx. f.) heartwood and sapwood, and redwood (*Sequoia sempervirens* D. Don Endl.).
- 2 Nosebar opening—Vertical, 0, 3, 6, 9, 15 per cent less than the veneer thickness; Horizontal, 0.025 inches.
- 3 Temperature—80°, 120°, 160°, and 200°.
- 4 Veneer thickness—0.125 inch.
- 5 Clearance angle—90 degrees.
- 6 Cutting angle—70 degrees.
- 7 Sharpness angle—20 degrees.
- 8 Nosebar angle—15 degrees.
- 9 Cutting velocity—67 feet per minute.
- 10 Mechanical tests—Tension perpendicular to the grain, compression perpendicular to the grain, and rolling shear.

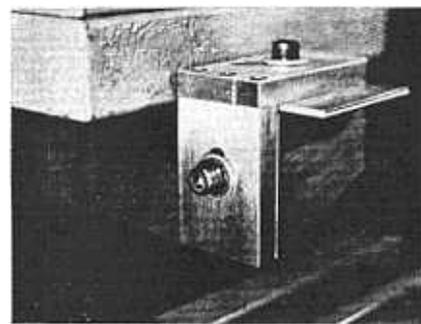


Fig. 3.—Assembled orthogonal veneer-cutting fixture showing method of using reference faces to position the nosebar.

The above species were selected to represent a hardwood and a softwood both of commercial importance and of widely divergent physical and mechanical properties. Both the sapwood and heartwood of yellow birch were selected for consideration since field observations indicate that each displays distinct veneering characteristics.

Vertical nosebar openings were selected to represent a range from zero pressure to pressure resulting in over-compression of the veneer. Geometrical cutting relationships were selected from current veneer-cutting practice.

In addition, limited consideration was given to the determination of the coefficient of friction for the above-mentioned woods. This was deemed necessary, since previous wood-machining studies have indicated the importance of frictional forces (5).

Orthogonal Veneer-Cutting System: Because orthogonal cutting of veneer necessitated the development of a new approach to veneer research, a detailed description of the cutting fixture is necessary.

Any cutting system developed should meet the following general requirements: 1) the system must allow for accurate, easy adjustment of the nosebar in both the horizontal and vertical directions, 2) deflection of the nosebar and knife as a result of cutting forces must be at a minimum, 3) the device must be of sufficiently heavy construction to allow secure positioning of the



Fig. 4.—Orthogonal veneer-cutting system, showing cutting fixture, milling machine and vise.

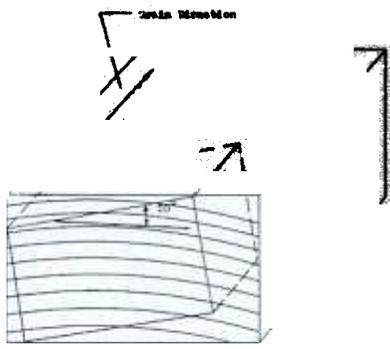


Fig. 5.—Sketch showing method of cutting veneer test specimens to obtain a favorable growth ring orientation.

knife and nosebar, and 4) the system must incorporate a means for obtaining accurate and uniform relative motion between the cutting edge and the work.

The cutting fixture developed is pictured in Figs. 2 and 3. Precise positioning of the nosebar and knife may be accomplished with two accurately machined reference faces. The knife, attached to the bottom surface by two large bolts, was slotted so that after sharpening it could be moved forward to the plane of the reference face from which horizontal nosebar adjustment was determined. The nosebar was adjusted in both the horizontal and vertical directions by shims placed on the two reference faces. The cutting angle was determined by the angle between the bottom face and the horizontal.

A milling machine provided a satisfactory method of traversing the work piece while holding the cutting apparatus stationary. The specimens were held in place by a vise affixed to the milling-machine table. The cutting fixture was mounted on an extension of the machine head after the arbor had been removed. By movement of the table, a portion of the specimen passed between the knife and nosebar to form a small veneer strip. Fig. 4 pictures the assembled orthogonal cutting system.

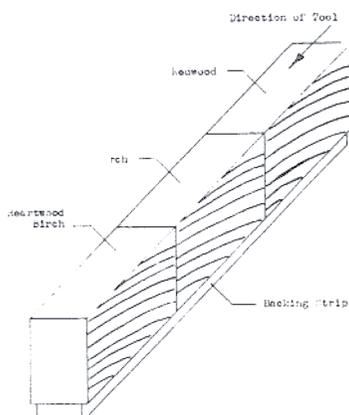


Fig. 6.—Sketch showing work piece unit consisting of a specimen of sapwood and heartwood yellow birch and redwood.

Preparation of Test Specimens: In the selection of material for study, it was necessary to impose several restrictions to minimize variation in wood properties and to facilitate accurate analysis of the influence of wood properties on veneer quality. The following restrictions were placed on all test material: 1) only straight-grained, defect-free, even-growth material was used, 2) all veneer and mechanical test specimens were end-matched to minimize specific gravity variation, and 3) all specimens were taken from the same band of growth rings.

Samples of redwood, heartwood yellow birch, and sapwood yellow birch that meet the above requirements were obtained in the green condition and stored in vapor-proof wrapping until cut into test specimens. Green wood was selected so that the test material would be reasonably free from internal defects and stresses resulting from drying. Each board was cut into three parts, veneer-cutting specimens being cut from the central portion, and mechanical test specimens from the end portions.

The veneer test specimens, 4 inches by $2\frac{1}{2}$ inches across the grain and $1\frac{1}{2}$ inches along the grain, were cut from the stock with the growth rings orientated at an angle of approximately 20 degrees to the surface to be machined (Fig. 5). A veneer test specimen from each of the three wood samples was then attached to a backing strip for convenience in handling (Fig. 6), with the growth rings positioned so that the springwood portion of each increment would first be presented to the tool edge. Thus, a uniformly favorable cutting condition was obtained in accordance with the findings of Lutz (3). The composite work unit was held in water at room temperature until use to make certain the material remained above the fiber saturation point.

Two specimen blanks for each of the three types of mechanical tests to be conducted at the four temperature levels were cut from the end portions of each wood sample.

A cleavage specimen was used to determine strength values in tension perpendicular to the grain, since it was reasoned to be a more realistic test than the standard tension specimen (5, 8). In both the cleavage and the shear-test specimens, certain departures from standard dimensions were necessary as a result of the saturated moisture condition and the manner of grain orientation (Fig. 7). Standard test-specimen dimensions were used to determine compression perpendicular to the grain (8).

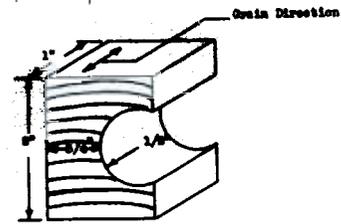
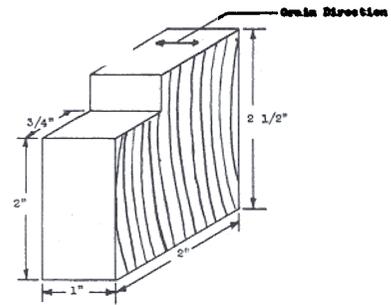


Fig. 7.—Sketch showing dimensions and grain orientation for rolling shear and cleavage test specimens.

All mechanical test specimens were stored in water at room temperature until used at the various temperature levels. Standard procedures were used to compute the individual mechanical properties.

Temperature Control: Temperature control for mechanical properties tests was accomplished by means of controlled-temperature baths. Before the specimens were tested, they were heated for two hours in water of the specified temperature. The specimens were then removed from the water and immediately tested. Preliminary experiments showed that the temperature drop during testing was negligible and that accurate values could be obtained in this manner.

A more complex means of temperature control was required during veneering. Before the veneer was cut, the work unit was heated in water of specified temperature for a period of two hours. Because of inherent delays in experimental procedure, the opportunity for temperature loss existed during cutting of the veneer strips. An external source of heat was therefore required to maintain the test specimens at a constant temperature. To accomplish this, a heavily insulated container with an electrical heating unit and thermostatic control was developed (Fig. 8). Water from the container was fed to a spray unit mounted in front of the work piece (Fig. 9), thus permitting the heated water to flow over the work and maintain the desired specimen temperature.

Method of Cutting: Prior to cutting, the sharpened veneer knife was advanced to the lower edge of the reference face, from which the horizontal nosebar opening was determined, and was securely bolted to the assembly. Precautions were taken to



Fig. 8.—General view of the experimental area, showing heating container for maintaining constant temperature during cutting of veneer.

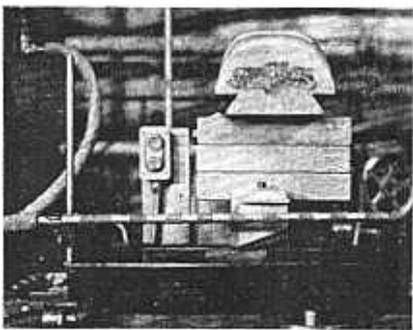


Fig. 9.—Water spray unit for maintenance of specimen temperature during cutting.

make certain the fixture established accurate orthogonal cutting conditions.

Sufficient shim stock was placed on the top reference face to raise the extreme edge of the nosebar to the cutting edge of the knife. By placing additional shim stock on the two reference faces, precise horizontal and vertical nosebar adjustment was accomplished. Adjustments of the nosebar were made during cutting at higher temperatures to compensate for thermal expansion of the cutting fixture.

The heated work unit of wood specimen was securely mounted in the vise, and water of specified tempera-

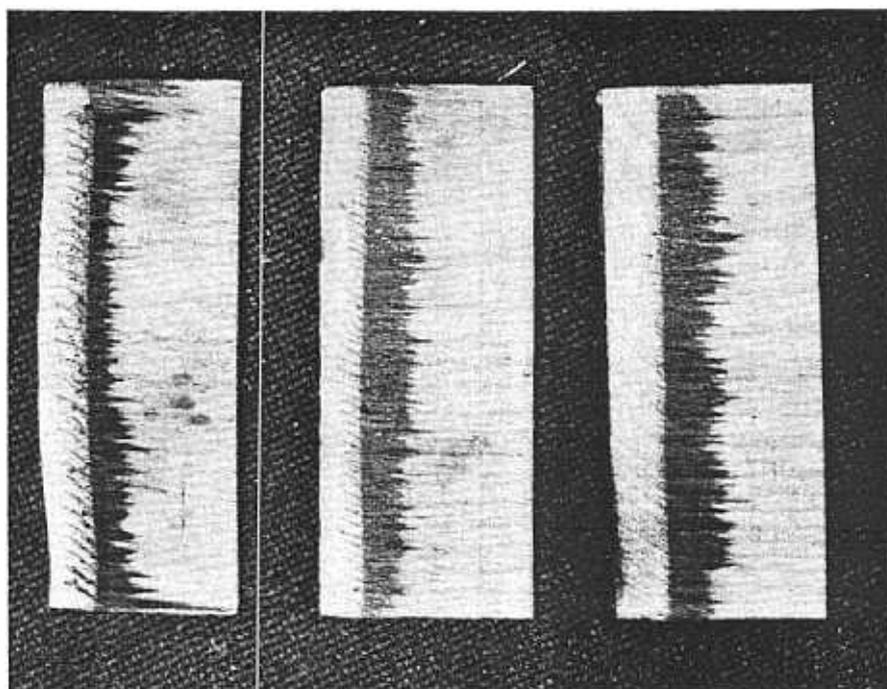


Fig. 10.—Veneer strips produced by orthogonal cutting, showing scarfed edge and exposed lathe checks.

ture was allowed to flow over the work unit as previously described. Several light cuts were made to assure a parallel surface with respect to the cutting edge of the knife. The milling-machine table was then raised 0.125 inch, and the work unit was advanced past the nosebar and knife. One veneer strip was cut and discarded to assure that the test veneer would have characteristic surface quality. After measurements were made for green thickness, the veneer strips were numbered consecutively for identification and placed under wire screens in a 16 per cent equilibrium moisture content conditioning room for a period of two weeks.

Additional consideration was given to the determination of instantaneous tool forces induced on the knife during

cutting by employing a two-component dynamometer. The dynamometer and experimental method employed is described in an analysis of the wood-cutting process by Franz (5).

Interpretive Techniques: To be considered of the highest quality, veneer must be 1) of minimum surface roughness, 2) uniform in thickness, and 3) free from lathe checks. It was recognized that the variables under consideration would produce veneer that would fail in one or more of the above considerations. It was therefore felt desirable to have three independent measures of veneer quality.

The frequency and depth of lathe checking was determined for each veneer strip. By lightly staining the loose side with a fast-drying alcohol stain and beveling a half-inch surface on

Table 1.—SUMMARY OF QUALITY DETERMINATIONS FOR SAPWOOD YELLOW BIRCH MACHINED AT VARIOUS NOSEBAR OPENINGS AND TEMPERATURES

Temp., ° F.	Nosebar opening, per cent	Checking frequency	Depth of check, in.	Dry thickness, in.	Green thickness, in.
80	0	10.5	0.079	0.124	0.129
80	3	12.0	0.069	0.124	0.129
80	6	13.3	0.062	0.124	0.128
80	9	17.0	0.049	0.123	0.126
80	15	22.0	0.031	0.116	0.121
120	0	10.4	0.069	0.123	0.128
120	3	12.0	0.065	0.124	0.129
120	6	15.0	0.033	0.123	0.128
120	9	19.0	0.023	0.122	0.127
120	15	23.0	0.018	0.114	0.118
160	0	10.0	0.048	0.131	0.136
160	3	14.5	0.032	0.123	0.128
160	6	18.0	0.023	0.120	0.125
160	9	21.0	0.022	0.120	0.124
160	15	27.5	0.015	0.114	0.119
200	0	16.5	0.023	0.129	0.133
200	3	33.0	0.021	0.126	0.129
200	6	39.0	0.020	0.123	0.126
200	9	51.0	0.013	0.121	0.125
200	15	0	0	0.118	0.121

Table 2.—SUMMARY OF QUALITY DETERMINATIONS FOR HEARTWOOD YELLOW BIRCH MACHINED AT VARIOUS NOSEBAR OPENINGS AND TEMPERATURES

Temp., ° F.	Nosebar opening, per cent	Checking frequency	Depth of check, in.	Dry thickness, in.	Green thickness, in.
80	0	8.7	0.063	0.124	0.129
80	3	11.0	0.063	0.124	0.130
80	6	12.3	0.073	0.124	0.130
80	9	15.7	0.049	0.122	0.127
80	15	22.0	0.027	0.118	0.123
120	0	9.0	0.060	0.124	0.130
120	3	10.7	0.072	0.124	0.130
120	6	14.0	0.052	0.121	0.127
120	9	15.0	0.040	0.118	0.125
120	15	18.7	0.029	0.114	0.120
160	0	9.3	0.066	0.130	0.137
160	3	10.7	0.045	0.121	0.123
160	6	16.3	0.023	0.121	0.127
160	9	20.3	0.022	0.121	0.127
160	15	50.0	0.012	0.117	0.123
200	0	16.0	0.024	0.125	0.130
200	3	23.0	0.015	0.124	0.129
200	6	25.0	0.014	0.120	0.125
200	9	39.0	0.007	0.120	0.125
200	15	0	0	0.119	0.124

the stained edge (9), lathe checks were exposed as dark lines extending through the thickness of the veneer (Fig. 10). The number of checks exposed over a 3-inch length was determined, and the frequency of checking was expressed as checks per inch of length. The average depth of check penetration was determined by applying the ratio of bevel length and dry thickness to the average length of the checks exposed on the scarfed surface.

Veneer thickness was determined at 5 equi-distant points along the length of the veneer strip in the green and dry condition with micrometer calipers. The thickness of the veneer was considered to be the average of the five measurements. Visual examination served to establish surface quality.

Results of Veneer Quality Determinations

As previously implied, machining conditions were such as to produce veneer of a wide range of quality. Data obtained from quality determinations are summarized in Tables 1 through 3. Relationships and trends extracted from these data are shown graphically in Figs. 11 through 14.

From the data, it will be noticed that veneer thickness measured in the green condition was greater than the nominal cutting dimension of 0.125 inch. It was observed that the increased thickness was accompanied by a corresponding shortening of the veneer along the cutting direction. These phenomena are similar to those in the machining of metals as described by Merchant (10).

Table 3.—SUMMARY OF QUALITY DETERMINATIONS FOR REDWOOD MACHINED AT VARIOUS NOSEBAR OPENINGS AND TEMPERATURES

Temp., ° F.	Nosebar opening, per cent	Checking frequency	Depth of check, in.	Dry thickness, in.	Green thickness, in.
80.	0	6.5	0.123	0.130	0.132
80.	3	7.5	0.115	0.129	0.130
80.	6	9.0	0.107	0.129	0.130
80.	9	10.5	0.100	0.127	0.128
80.	15	12.0	0.098	0.122	0.124
120.	0	6.0	0.089	0.129	0.130
120.	3	8.0	0.083	0.127	0.130
120.	6	10.0	0.075	0.127	0.129
120.	9	12.5	0.070	0.126	0.127
120.	15	18.0	0.044	0.121	0.123
160.	0	0	0	0.129	0.132
160.	3	0	0	0.129	0.131
160.	6	0	0	0.128	0.130
160.	9	0	0	0.127	0.128
160.	15	0	0	0.124	0.126
200.	0	0	0	0.129	0.130
200.	3	0	0	0.126	0.129
200.	6	0	0	0.125	0.128
200.	9	0	0	0.125	0.127
200.	15	0	0	0.122	0.124

The reduction in veneer thickness with smaller nosebar openings suggests that the attending pressures were sufficient to cause compression set of the wood fibers. Due to the rigidity of the nosebar, the amount of wood compression was positive, and deformation rather than strength in compression perpendicular to the grain appears to be the limiting factor. This is evidenced by measurements of green and dry thickness dimensions, which display relatively uniform differences at all nosebar pressures and thus reflect uniform shrinkage from the green thickness during drying.

An interrelationship appears to exist between temperature, nosebar pressure, checking frequency, and depth of check penetration. Checks of low frequency were characteristically severe in penetration, while checks of high

frequency were relatively shallow. Figs. 11 through 14 reveal that lathe checking was materially reduced by increasing nosebar pressure or cutting temperature.

In general, the surface roughness of all woods tested decreased with an increase in temperature or nosebar pressure. In the case of yellow birch, surface quality appeared related to the severity of checking. Shallow checks of high frequency were in all cases indicative of good surface quality. With redwood, however, surface quality did not appear to be so closely correlated with checking. Although no checking was observed when machining was done at 160° F., surface roughness was severe and only slight improvement was noted when veneering at 200° F.

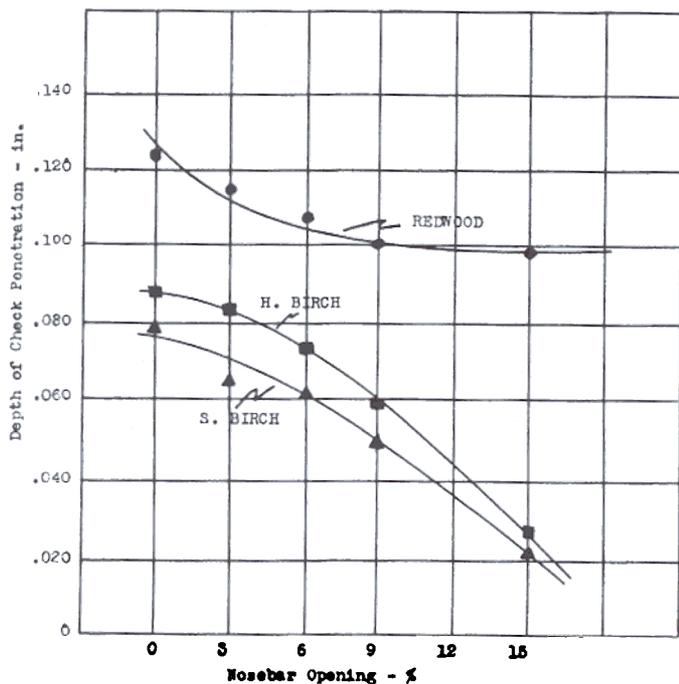


Fig. 1.—Relation of nosebar pressure to depth of check penetration for woods machined at 80° F.

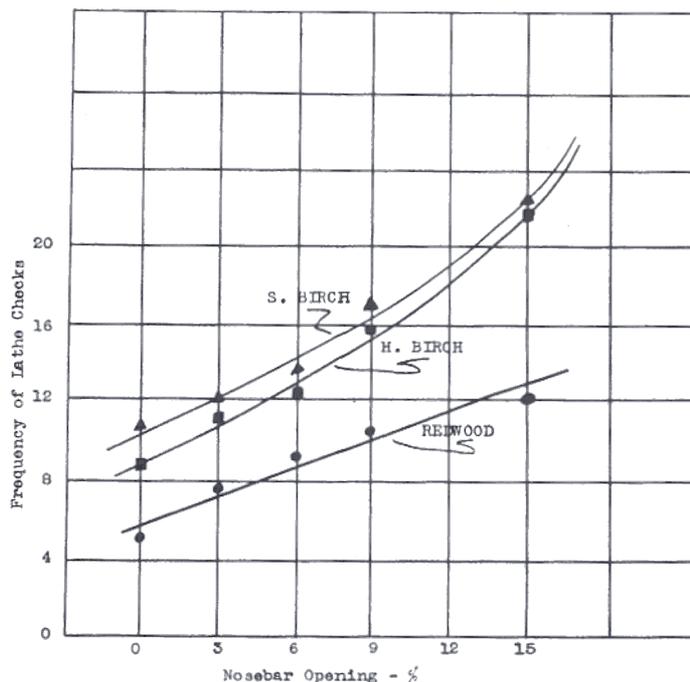


Fig. 12.—Relation of nosebar pressure to frequency of lathe checks for woods machined at 80° F.

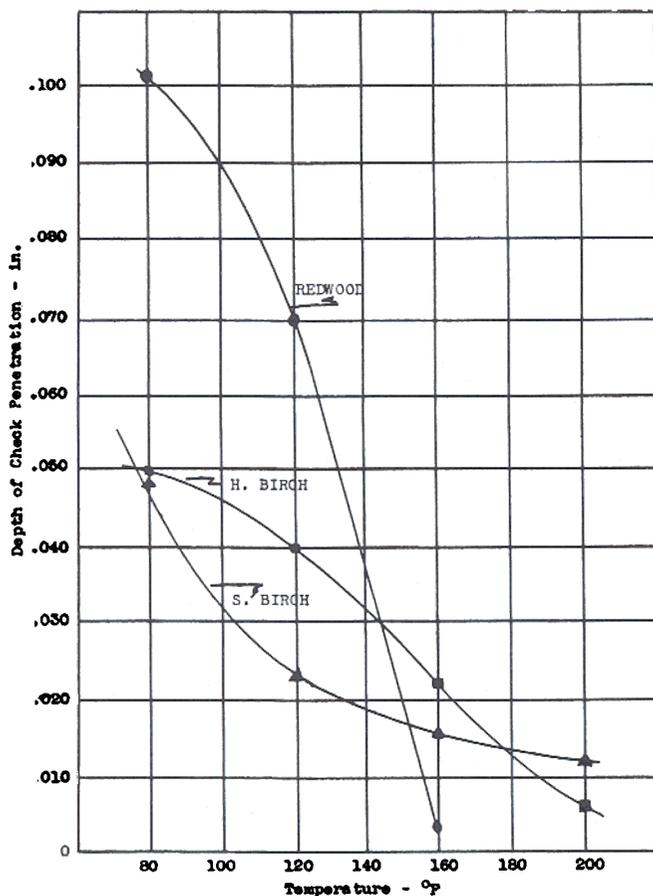


Fig. 13.—Relation of temperature to depth of check penetration for woods machined with vertical nosebar opening of 9 per cent.

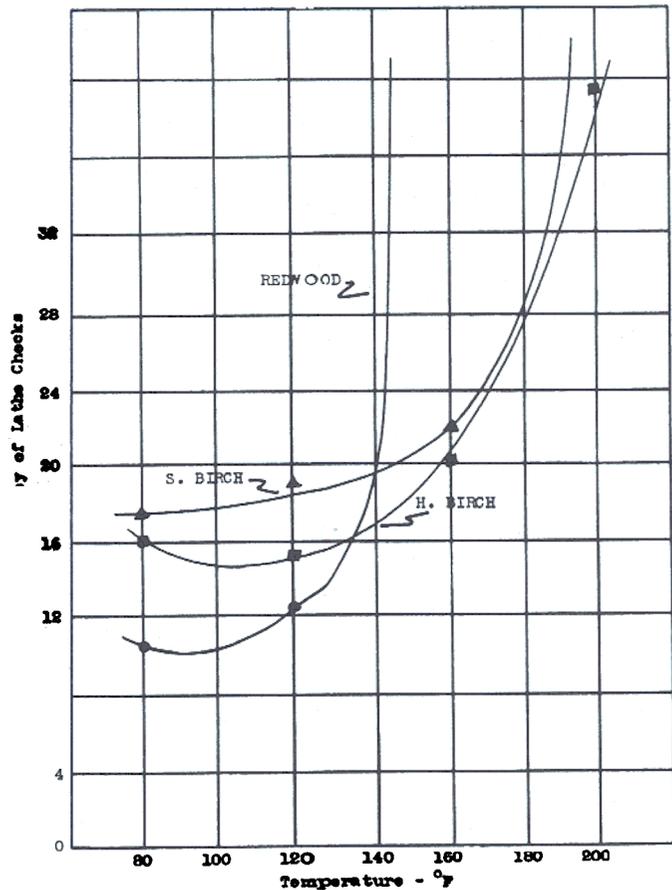


Fig. 14.—Relation of temperature to frequency of lathe checks for woods machined with vertical nosebar opening of 9 per cent.

Results of Mechanical Properties Tests

The mechanical properties and coefficient of friction for redwood, sapwood yellow birch, and heartwood yellow birch were determined at the prescribed temperature levels. Data obtained are summarized in Table 4 with graphical representations shown in Figs. 15 through 18. Only those properties considered to be pertinent to the veneer-cutting process are included.

The tensile stress in cleavage was calculated by the equation for eccentric loading (11),

$$S = \frac{F}{A} + \frac{Fec}{I} \text{ where,}$$

S = stress in tension, in pounds per square inch

F = the applied load, in pounds

A = the area under stress, in square inches

e = the eccentricity of the applied load, in inches

c = the centroidal distance of area A, in inches

I = moment of inertia of area A.

The coefficient of friction was calculated from the equation used by Franz (5) in a study of the wood-cutting process.

$$u = \tan \left(\arctan \frac{K_n}{K_p} + C \right)$$

u = the coefficient of friction

K_n = the normal force component on the knife

K_p = the parallel force component on the knife

C = the cutting angle

It may be noted that values obtained for the coefficient of friction are very high, and in some cases greater than one. Similarly high values for the coefficient of friction have been reported by Ernst and Merchant in metal machining studies (12).

Discussion of Observational Data

Veneer Type: It has been shown in previous wood-machining experi-

ments that the cutting process is defined by the nature of wood failures ahead of the cutting edge, and that these failures are a function of wood mechanical properties and cutting geometry (5). These findings can be demonstrated to be applicable to the veneering process. Observations made during the formation of veneer show that basic veneer types are generated which display identifying characteristics. It is suggested, therefore, that veneer type can be associated to wood properties and cutting conditions by means of analysis of force relationships.

Two basic types of veneer were distinguishable in this study:

Table 4.—SUMMARY OF MECHANICAL PROPERTIES AND COEFFICIENT OF FRICTION DETERMINED FOR WOODS TESTED AT VARIOUS TEMPERATURES

Temp., ° F.	Tension perpendicular to the grain psi	Rolling shear psi	Compression perpendicular to the grain psi at P.L.	Coefficient of friction
REDWOOD				
80.	820	241	815	1.18
120.	260	202	272	1.06
160.	192	169	240	1.82
200.	141	128	161	
SAPWOOD YELLOW BIRCH				
80.	987	619	684	0.99
120.	696	572	579	0.86
160.	571	488	389	0.61
200.	360	340	261	
HEARTWOOD YELLOW BIRCH				
80.	917	513	747	0.87
120.	792	445	517	0.71
160.	696	350	409	0.78
200.	390	259	297	

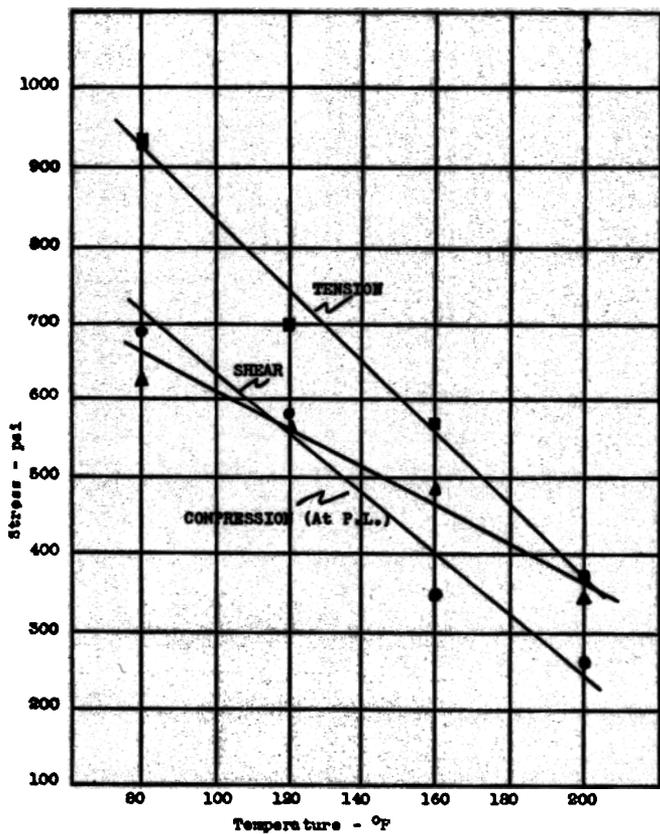


Fig. 15.—Relation of sapwood yellow birch mechanical properties to temperature.

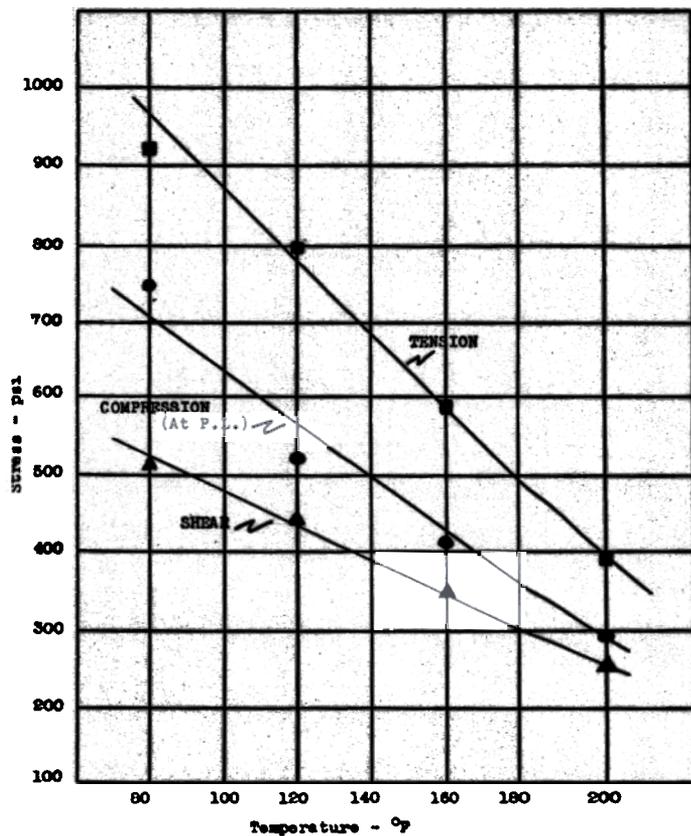


Fig. 16.—Relation of heartwood yellow birch mechanical properties to temperature.

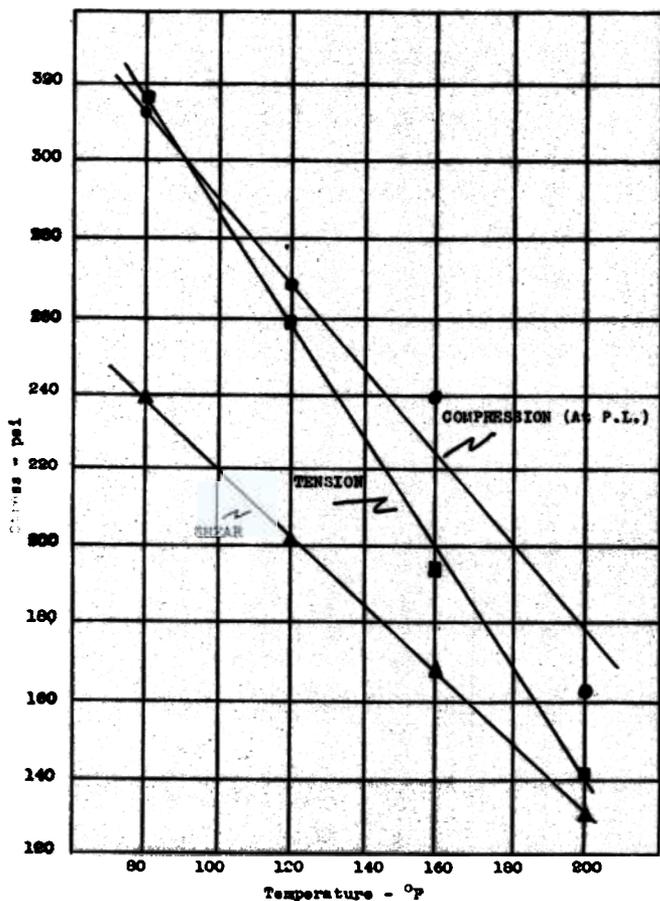


Fig. 17.—Relation of redwood mechanical properties to temperature.

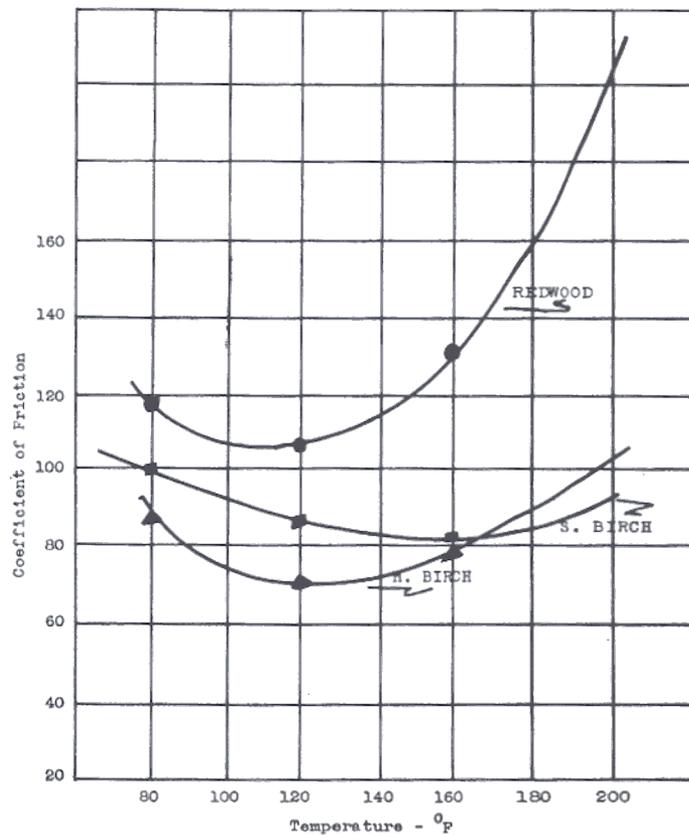


Fig. 18.—Relation of coefficient of friction of woods tested to temperature.

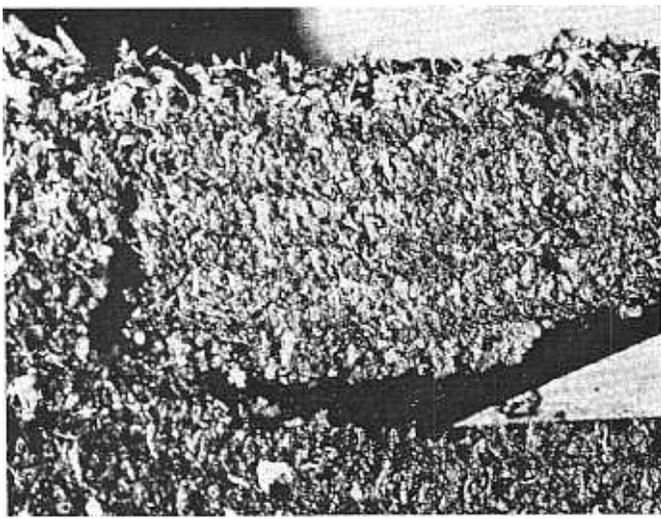


Fig. 19.—Type A veneer, showing split portion ahead of the knife and failure as a beam.

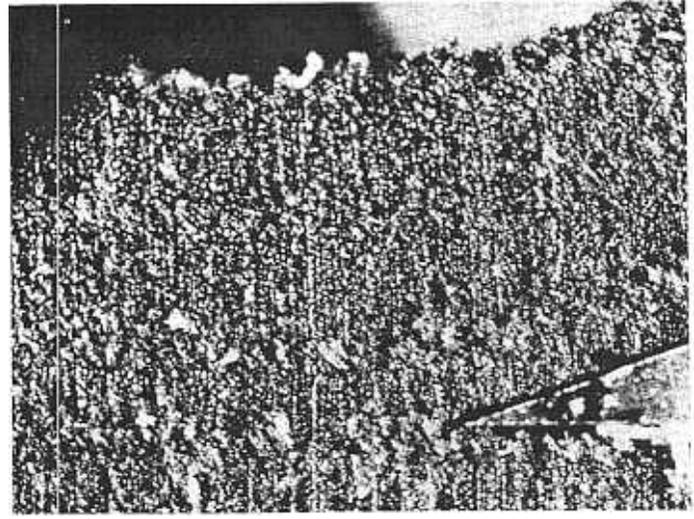


Fig. 20.—Type B veneer, showing development of continuous tension failure perpendicular to the cutting path.

Type A veneer is formed when cutting conditions are such that the wood splits ahead of the knife by shear and compression until failure of the split portion occurs in bending as a cantilever beam, as shown in Fig. 19.

Type B veneer occurs when tool forces cause continuous tension failures in a direction perpendicular to the cutting path, as indicated in Fig. 20.

Formation of Type A Veneer: Type A veneer appears to be produced through a cyclic series of events. At the start of the cycle, the knife advances to the work edge and produces localized areas stressed in tension in a direction perpendicular to the cutting path (Fig. 21). Continued movement of the knife relative to the work strains the wood ahead of the tool, produces failure in tension perpendicular to the grain at the knife edge, and induces stress in compression perpendicular to the grain and rolling shear acting in a plane parallel to the cutting path. A sudden splitting failure occurs ahead of the knife edge when the ultimate strength of the wood in rolling shear has been exceeded. As the knife advances, the split portion is deflected up the face of the knife and is stressed in bending as a cantilever beam. As bending progresses, stresses become critical and failure occurs as a cantilever beam at the point of maximum moment (Fig. 21). Continued movement of the knife relative to the work may produce additional deflection and accentuate the failure until the cutting edge contacts the point of bending failure and initiates the start of another cycle. Repetition of the above series of events produces veneer that contains severe lathe checks and rough surface characteristics.

Maximum tensile stresses develop at the point of maximum moment of the cantilever beam. Thus, the location of

the ultimate check with respect to subsequent cycles is clearly dependent upon the length of the split. The length of the splitting failure appears to be determined by the strength of the wood in rolling shear and compression perpendicular to the grain.

The magnitude of tensile stress that a wood may sustain before failure through bending determines, in part, the depth of check penetration. The depth of check penetration may, as previously discussed, be increased by additional deformation after bending failure has occurred.

Several factors appear conducive to formation of Type A veneer. In the work, low resistance in compression perpendicular to the grain and rolling shear when accompanied by relatively high tensile strength perpendicular to the cutting path favor development of the splitting failures and ruptures due to accompanying bending stresses. From the geometry of veneer-cutting, it can be shown that a low coefficient of friction at the interface of the knife and the work as well as tool force distributions attending the large cutting angle are also contributing factors.

Type B Veneer Formation: Veneering conditions may, within a limited range, favor the development of a continuous tension failure that extends in a plane parallel to the cutting path. In the formation of Type B veneer, relative movement of the knife along the cutting path strains the wood ahead of the tool in tension perpendicular to the grain (Fig. 22). Continued advancement of the knife produces failure in tension at the knife edge and induces compression and rolling shear stresses parallel to the cutting path. The induced stresses are not exceeded in ultimate strength, however, and the splitting failure associated with Type A veneer does not develop. Deformation

resulting from additional movement of the knife induces tensile stress perpendicular to the cutting path which ultimately exceeds the strength of the wood in tension perpendicular to the grain. Thus, wood failure more closely approximates a continuous peeling action.

The continuous, uniform process of wood failure described above results in veneer that contains no lathe checks and is of superior surface characteristics. Type B veneer, therefore, represents the ideal veneer from the standpoint of quality.

The production of Type B veneer appears to be a balance between force relationships and mechanical properties. Factors contributing to formation of Type B veneer include the following: 1) relatively low strength in tension perpendicular to the grain as compared with strength in compression perpendicular to the grain and rolling

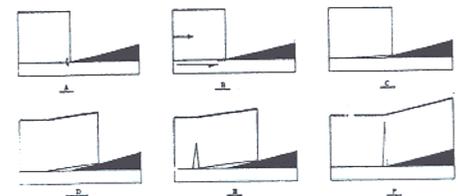


Fig. 21.—Sketch showing development of type A veneer. A, initial contact of the knife; B, straining of the wood at instant before failure; C, splitting of wood ahead of cutting edge; D, bending as a cantilever beam; E, failure as a cantilever beam; and F, accentuation of bending failure.



Fig. 22.—Sketch showing development of type B veneer. A, initial contact of the knife; B, straining of the wood at instant before failure; C, peeling of wood ahead of the knife.

shear, and 2) high coefficient of friction between the knife face and the work.

The significance of force relationships within the veneer particle, as influenced by the presence or absence of nosebar pressure, will be discussed in subsequent paragraphs.

Discussion of Mechanics of Veneer Formation

An exact theoretical stress analysis of the veneering process is confounded by complex stress distributions and the anisotropic nature of wood. An approximate solution, however, can be developed that is in reasonable agreement with observational data of veneer types, mechanical properties, and quality determinations.

Nosebar Pressure Absent: Although the use of nosebar pressure is accepted practice, it is felt that pressure may be completely relieved during the veneering process through 1) changes in the veneer thickness resulting from surface irregularities, or 2) deflection in mechanical elements of the lathe.

If the undeformed veneer is considered to be a particle held in mechanical equilibrium, Fig. 23 approximates the force relationships existing when no nosebar pressure is applied. The advancing knife exerts a resultant force R_K on the undeformed particle. This resultant force may be resolved into a horizontal component K_p and a vertical component K_n . K_p is resisted by a compressive force F_c acting over area w of the undeformed particle and a rolling shear force F_s acting in the plane of the cutting edge. The forces F_s and K_n tend to rotate the undeformed particle, and are resisted by internal moment M that originates in the work. This resisting moment may be considered to develop through bending of the particle as a cantilever beam and from tensile stresses distributed along the lower surface of the particle in a direction normal to the cutting path. The magnitude of these resisting forces are determined by the amount of bending present in the particle.

The force relationships described above favor the production of Type A veneer. Woods with relatively high strength in tension perpendicular to the grain appear to fail in compression and shear before the ultimate strength in tension can be exceeded. Thus, the characteristic splitting failure occurs, which ultimately results in a lathe check.

Strength properties within the undeformed particle may be such as to result in Type B veneer, even though no nosebar pressure is applied to the particle. If the limiting stress in ten-

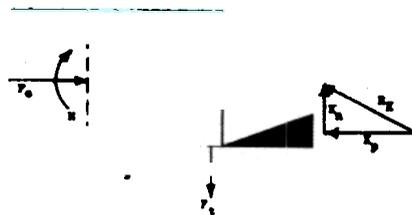


Fig. 23.—Force system suggested for discussion of mechanics of veneer-cutting. Nosebar pressure absent.

sion perpendicular to the grain is low with respect to strength in compression and rolling shear, conditions are favorable to a continuous tension failure in a plane parallel to the cutting path. The forces applied to the particle by the knife produce failure in tension before the limiting compressive and shear values can be exceeded, and the peeling action previously described as producing Type B veneer results.

Nosebar Pressure Present: Fig. 24 approximates the force relationships that exist in the undeformed veneer particle when the effects of nosebar pressure are taken into consideration. As in the absence of nosebar pressure, the advancing knife exerts resultant force R_K on the undeformed particle, and is resolved in horizontal and vertical components K_p and K_n . The nosebar exerts resultant force R_N to the particle, and is resolved into horizontal and vertical components N_p and N_n . The force components K_p and N_p are resisted by compressive force F_{cp} and shearing force F_s . The component N_n is resisted by compressive force F_{cn} , while force K_n is resisted by tensile force F_t .

Non-colinearity of the horizontal and vertical force components of the knife and nosebar tends to rotate the particle under consideration, and thereby creates compressive stresses at the upper surface of the particle and large tensile stresses perpendicular to the cutting path near the knife edge. In response to these stresses, the particle is initially strained so that bending stresses resulting from deflection of the veneer by the knife are minimized. The above force relationships favor the production of Type B veneer.

Without nosebar pressure, tensile strength perpendicular to the grain often cannot be sufficiently reduced by temperature adjustment to produce the desired continuous tension failure and production of Type B veneer. The application of nosebar pressure to the particle, however, creates sufficient initial tensile stress so that the additional stress resulting from the advancing knife exceeds the ultimate strength of the wood in tension perpendicular to the grain, thus producing the desired peeling action.

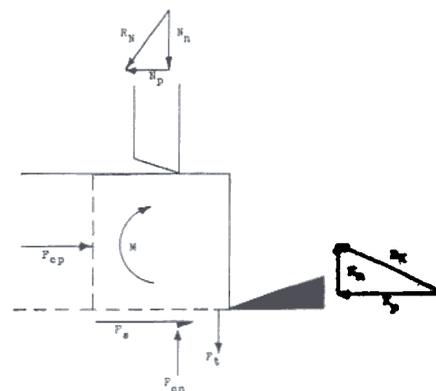


Fig. 24.—Force system suggested for discussion of mechanics of veneer-cutting. Nosebar pressure present.

The amount of nosebar pressure required to create sufficient tensile stress for production of Type B veneer appears to be a balance between force relationships and mechanical strength. If the limiting strength of the material in tension perpendicular to the grain does not approach or fall below the limiting strength in rolling shear and compression, additional nosebar pressure is required to produce the desired tensile stress in the veneer particle. If nosebar pressure is insufficient or if tensile strength is high relative to the strength in rolling shear and compression, Type A veneer will be produced. Thus, with the application of controlled nosebar pressure, the occurrence of lathe checks may be reduced or eliminated.

As previously stated, high frictional forces appear to favor the production of Type B veneer. From the geometry of cutting, it can be shown that large frictional forces at the interface of the knife and the wood have the net effect of reducing tensile stresses resulting from bending.

Application of Visual Observations and Theoretical Analysis to Quality and Mechanical Properties Data

Comparison of Tables 1 through 3 show that, as machining conditions approach those required for production of Type B veneer, the severity of checking and surface roughness are reduced. It will be noted that, although severity of checking is reduced by the application of nosebar pressure, the formation of Type B veneer requires that tensile strength of the material be low as compared to compressive and shearing strength.

Table 1 indicates the sapwood of yellow birch to have slightly superior veneering characteristics when veneered below 200° F. Figs. 15 and 16 show that tensile strength as compared to shearing and compressive strength is more favorable for production of Type

B veneer in the sapwood. In addition, it has been shown that the sapwood is tougher than the heartwood (12).

When yellow birch was machined at 200° F., the depth of check penetration was observed to be shallower in the heartwood than in the sapwood. At 200° F., the relative strength properties conducive to formation of Type A veneer are slightly in favor of the sapwood. However, coefficient of friction data (Fig. 18) suggest that at approximately 180° F. frictional forces exerted on the heartwood become greater than those on the sapwood and thus reflect the improved heartwood veneer quality.

Table 3 shows that redwood contained no checks when machined at 160° F. and 200° F., regardless of the nosebar opening used. Fig. 17 reveals that at approximately 160° F. the tensile strength, as compared to the compressive and shearing strengths, approaches the conditions favorable for formation of Type B veneer. In addition, Fig. 18 indicates that high frictional forces are imposed on the veneer particle.

Conclusions

The research summarized above suggests a number of conclusions regarding the veneer-cutting process.

1. The veneer-cutting process is characterized by two extreme types of veneer formation: 1) veneer formed by a splitting and bending process and containing severe lathe checks and

rough surface qualities, and 2) veneer formed by a peeling process and characterized by the absence of lathe checks and superior surface qualities.

2. The quality of veneer formed under a given set of veneering conditions is determined by the nature of wood failure ahead of the knife.

3. The surface quality generated is a function of wood failure.

4. The type of wood failure, and hence veneer quality, is a function of wood properties and force relationships within the veneer particle.

5. Mechanical properties define the nature of wood failure under a given force system.

6. Nosebar pressure influences veneer quality by establishing additional forces within the veneer particle.

7. Frictional forces at the knife face are important because they affect force relationships within the veneer particle.

8. Wood mechanical properties that appear to have the most significant effect on veneer quality are: compression perpendicular to the grain, tension perpendicular to the grain, and rolling shear.

9. For the woods tested, tension perpendicular to the grain is reduced more than compression perpendicular to the grain and rolling shear with an increase in temperature.

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